Scaling Analysis of the China France Oceanography Satellite Along Track Wind and Wave Data

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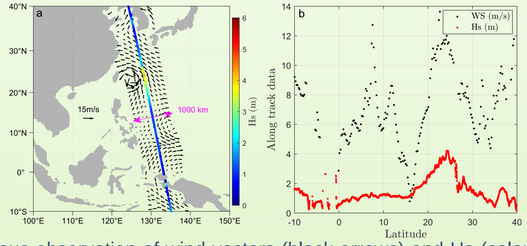
Abstract

Fourier power spectrum analysis and second-order structure function analysis are performed to the China France Oceanography Satellite along track wind speed (WS) and significant wave height (Hs) data. The measured Fourier power spectrum of WS data exhibits power-law features in the ranges of 30 to 2500 km with the scaling exponents β close to 5/3 and 2 in the higher and lower wavenumber ranges respectively. For Hs data, the Fourier power spectrum illustrates similar scaling behaviors. The measured second-order structure functions confirm the existences of the existence of power-law features. Furthermore, the latitudinal variations of scaling exponents are observed. Our preliminary results confirm the relevance of using multiscale statistical tools to characterize the movement of both ocean and atmosphere.

Data

- Wind-field scatterometer provided wind speed (WS) data with swath width of about 1000 km in 12.5 km resolution.
- Surface waves investigation and monitoring radar observed significant wave height (Hs) data in a resolution about 1.5 km.
- WS data are from December 18, 2018 to present.
- Hs data are from July 29, 2019 to present.
- The lines longer than 7000 km and have 95% or more good data are accepted to do Fourier power analysis.



(a)Simultaneous observation of wind vectors (black arrows) and Hs (color dots) by CFOSAT on September 4, 2019 in the west Pacific Ocean. (b) The corresponding WS (black dots) in the center of swath and the Hs (red dots) along the track.

Method

1) Fourier power spectrum analysis

$$E(k) = \int_{-\infty}^{+-\infty} \rho(r)\cos(2\pi kr)\,dr \qquad E(k) \propto k^{-\beta}$$

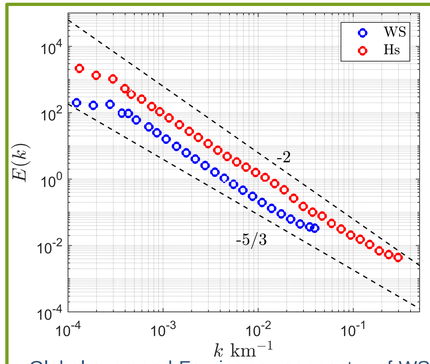
$$\rho(r) = \frac{1}{M(r)}\sum_{i=1}^{M(r)} \tilde{\theta}(x_i + r)\tilde{\theta}(x_i) \qquad \tilde{\theta}(x_i) = \theta(x_i) - <\theta(x_i)>$$

2) Structure function analysis

$$S_q(r) = <|\Delta\theta_r|^q> \qquad S_q(r) \propto r^{\zeta(q)}$$

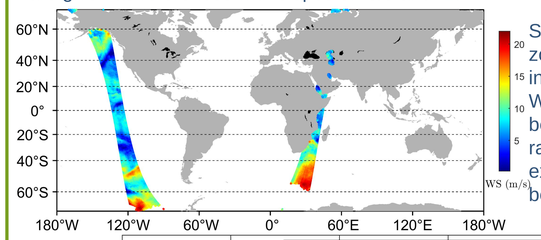
$$\Delta\theta_r = \{\theta_i - \theta_j\}|_{r_{ij}=r}$$

Fourier power spectrum analysis

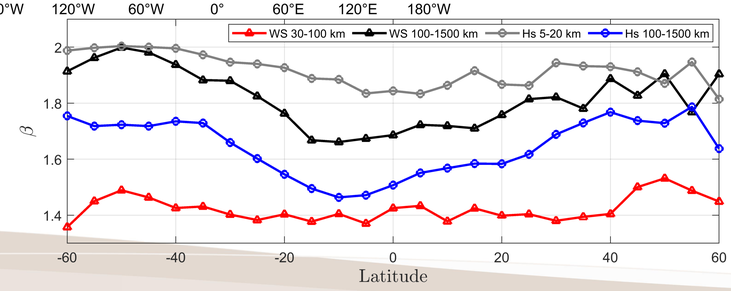


Power-law features can be observed in the global averaged Fourier power spectra of WS and Hs. For both spectra, the scaling exponent β close to 5/3 in higher wavenumber ranges and close to 2 in lower wavenumber ranges.

Global averaged Fourier power spectra of WS (blue cycles) and Hs (red cycles). Dashed lines are given as references with slopes of -5/3 and -2.

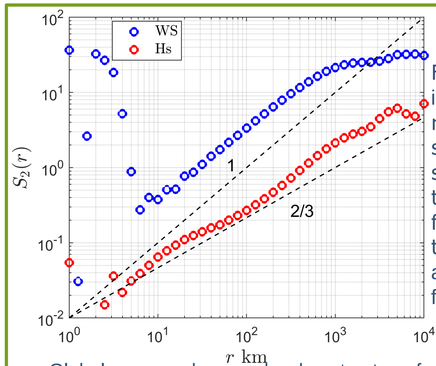


Slice the world ocean into 20 degrees zonal bands to characterize the influence of latitude on the spectra of WS and Hs. Power-law features can be observed in different spatial ranges. The corresponding scaling exponents β are illustrated in the bottom figure.



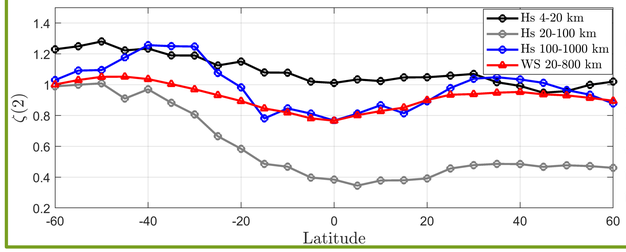
The scaling exponents β measured from the WS and Hs data both show latitudinal variations. The maximum values occur at 50 degrees north and south of the equator. Measured β in the small scale show slight variations in low latitudes. In the spatial scale of 100 to 1500 km, β from the WS and Hs show similar variation trends along latitude, with the minimum values occur at around 10 degrees south of the equator.

Structure function analysis



For WS, the second-order structure function illustrates a power-law feature in the range from 20 to 800 km with the scaling exponent ζ(2) close to 1. For the second-order structure function of Hs, three power-law ranges can be found from 4 to 20 km, 20 to 100 km, and 100 to 1000 km, ζ(2) are close to 1 in the small and large scales, a relatively small ζ(2) is found in the middle scale.

Global averaged second-order structure functions of WS (blue cycles) and Hs (red cycles). Dashed line is given as a reference with slope of 1.



Measured ζ(2) from the WS and Hs data along latitude. Latitudinal variations of ζ(2) can also be found. ζ(2) of Hs in sub-mesoscale show slight variations. For the other cases, the minimum of ζ(2) occur at tropical regions.

Summary

(a) Scaling features of the CFOSAT along track wind and wave data are observed by the Fourier power spectrum analysis and second-order structure function analysis.

(b) The scaling exponents measured from the WS and Hs both illustrate latitudinal variations is different scales.